Marked-up Version of Specification:

PATENT APPLICATION

TITLE: METHOD FOR IMPROVED VERTICAL SWEEP OF OIL RESERVOIRS

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~~Cross-Reference to Related Application 60/469,700 Priority Date 5/12/2003~~

This application claims the benefit of U.S. Provisional Patent Application No. 60/469,700, filed May 12, 2003.

~~Technical Field~~

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention pertains to recovery of crude oil from subterranean reservoirs by injecting both water and a second less dense fluid to displace the oil, preferably through horizontal wells. The invention is based on the proper selection of spacing and relative location of injection and production wells, and proper selection of injection rates and location of injection completion intervals for both water and the second fluid.

~~Background Art~~

2. DESCRIPTION OF RELATED ART

Although gas efficiently displaces oil in a vertical downward displacement that is aided by gravity, gas displacement of oil by predominantly horizontal flow is inefficient because of the low viscosity of the gas relative to the oil. The gas fingers through the oil, giving poor conformance and resulting in a low recovery of the oil. Injecting water along with the gas was proposed to control this fingering and poor conformance. The water decreases the mobility of the gas by lowering the relative permeability of the formation to the gas. Field tests showed it was most feasible to inject the water alternately with the gas. This process is known as WAG flooding. The ratio of the volume of water injected to the volume of gas injected is the WAG

spacing and high enough injection rates to inhibit, but not to eliminate, gravity segregation. Huang et al.. in U. S. Pat. No. 5,320,170 issued June 14, 1994, propose using a combination of horizontal and vertical wells to counteract gravity, and claim a modest improvement in recovery by doing so. Stevens et al. in U. S. Pat. No. 5,634,520, issued June 3, 1997, claimed the use of short gas injection cycles to increase recovery, by achieving a more uniform vertical distribution of the gas injected. McGuire et al. in 1999 noted that the WAG flood at Prudhoe Bay is strongly gravity dominated, and the MI (*i.e.-second fluid*) sweeps oil near the injection well, but gravity segregation causes it to leave large areas of the reservoir unaffected. They proposed the use of both vertical & horizontal wells to inject the second fluid low in the formation in order to make gravity segregation take place over a greater distance, and therefore to require more time to occur. This increased time results in greater second fluid penetration into low levels of the formation, and hence greater oil recovery. Their test of a vertical well for this purpose did not give very favorable results. Drilling horizontal wells near the bottom of the formation for alternate water and MI injection worked better. They concluded that in a gravity dominated reservoir like Prudhoe Bay, this approach appears to be economically competitive with WAG flooding as proposed by Stone, see above. Both Edwards et al. in 2000 and Redman in 2002 confirmed the beneficial effect of such horizontal injection wells.

However, gravity segregation remains a problem in WAG flooding. The various methods proposed to control or reduce gravity segregation are often not economically feasible. They are expensive processes in themselves and/or they do not result in enough oil recovery to make them profitable. Other such methods are successful only in certain types of reservoirs or under certain reservoir conditions. Usually such methods, while appropriate for water floods or miscible slug drives, are not useful for improving the vertical conformance of a WAG flood. Methods are needed that will yield higher vertical conformance in a WAG flood.

~~Disclosure of Invention~~

SUMMARY OF INVENTION

In a WAG flood oil is displaced from a subterranean formation by injecting water alternately with gas through a single injection completion per pattern. The ratio of water to gas injected is the WAG ratio. Recovery using the prior art is severely limited by gravity segregation of the water and the second fluid. This invention increases recovery several-fold above that of

FIG. 15 shows the effect of the pattern area on the vertical sweep when vertical wells are used..

FIG. 16 shows the effect of the pattern area on the vertical sweep when horizontal wells are used.

~~Best Mode for Carrying Out the Invention~~

DETAILED DESCRIPTION OF THE INVENTION

In a preferred embodiment, only second fluid is injected into the bottom injection interval, and only water into the top. At selected times and for selected time periods, the water injection is stopped. During these periods, gravity will cause the continuing second fluid injection to flow into the upper injection interval. When water injection is resumed, it will move this second fluid into the formation and mix with it. The net effect is a high WAG ratio injection into the upper part of the reservoir that can be controlled by the frequency and length of the interruptions of the water injection. The frequency of these water stoppages should be high, and the length short. The length should be no greater than the time it takes the second fluid injected at the bottom to reach the top of the reservoir. One way of accomplishing this shortness is to have a detector for the second fluid located near the top of the reservoir directly above the second fluid injector, perhaps placed in or just outside the water injector. Preferably, this detector would automatically cause the water injection to resume.

Industrial Applicability

Application of this invention using horizontal wells generally yields several-fold higher oil recovery than does using vertical wells. Two such injection well bores are required for each pattern and should be completed along the full length of one edge of the pattern. This location will convert a 5-spot pattern into a line drive one. These well bores may be provided by two sidetracks from a single well, or completely different wells may be used. In either event, they should be drilled parallel to any existing unidirectional fracture system, to achieve the best horizontal sweep. This alignment with the fracture system and the line drive pattern gives horizontal wells a generally improved areal conformance compared to vertical wells, to complement their higher vertical sweep. In FIG. 1 these two well bores 14 and 16 penetrate Pattern Element 10 horizontally and are parallel to each other. Well bore 14 is near the bottom of the formation, and injection into it is predominately second fluid. If there is a water table present

Marked-up version of Claims

CLAIMS

What I claim is:

1. (original) A method for recovering oil from a pattern element of a subterranean formation, the formation having an upper boundary and a lower boundary, the pattern element having a lower completion interval for fluid injection and a higher vertically displaced completion interval for fluid injection and a completion interval for fluid production, comprising:

injecting a gas into the lower completion interval at a first selected gas injection rate for a selected time;

injecting water into the higher completion interval at a first selected water injection rate for a selected time;

decreasing water injection rate into the higher completion interval for fluid injection for a selected time, while maintaining a selected gas injection rate into the lower completion interval for fluid injection, so as to increase rate of gas flow upward in the formation and form a mixed flow zone in the formation between the lower completion interval and the upper boundary of the formation, then continuing water injection into the higher completion interval for fluid injection; and

recovering oil from the completion interval for fluid production.

2. (original) The method of claim 1 wherein the lower completion interval is in proximity to the lower boundary of the formation.

3. (original) The method of claim 1 wherein the higher completion interval is in proximity to the upper boundary of the formation.

4. (original) The method of claim 1 further comprising the step of injecting water at a selected WAG ratio into the lower completion interval for a selected time.

5. (original) The method of claim 1 further comprising the step of injecting gas at a selected WAG ratio into the higher completion interval.

6. (original) The method of claim 5 wherein the WAG ratio is obtained by setting the second selected water injection rate at zero for a selected time.

7. (original) The method of claim 1 further comprising adding a tracer to the gas or water before injection.

8. (original) The method of claim 1 further comprising adding a surfactant to the gas or water before injection.

9. (original) The method of claim 1 further comprising, after a selected time, forming vertically displaced completion intervals for fluid injection in place of the completion interval for production and reversing the direction of flow through the pattern element by injecting gas and water into the vertically displaced completion intervals for fluid injection and converting one of the completion intervals for injection into a completion interval for production.

10. (original) The method of claim 1 wherein the gas is selected from gases consisting of natural gas, natural gas containing heavier hydrocarbons, nitrogen, carbon dioxide, flue gas and mixtures thereof.

11. (original) The method of claim 10 wherein the gas is miscible with the oil.

12. (original) The method of claim 1 wherein the lower completion interval and the upper completion interval are formed in vertically displaced horizontal wellbores through the formation.

13. (original) The method of claim 1 wherein the lower completion interval and the upper completion interval are formed by perforated intervals in a vertical wellbore.

14. (original) A method for recovering oil from a pattern element of a subterranean formation, the formation having an upper boundary and a lower boundary, the pattern element having a lower completion interval for fluid injection and a higher vertically displaced completion interval for fluid injection and a completion interval for fluid production, comprising:

using predicted rock and fluid properties in the pattern element, conducting computer simulations of flow of reservoir fluids and injected gas and water in the pattern element, the injected gas and water being injected at selected rates for selected times, the gas being injected into the lower completion interval for fluid injection and the water being injected into the higher vertically displaced completion interval for fluid injection and fluid being produced from the completion interval for fluid production;

selecting the rate and times of gas injection and water injection based on the computer simulations to predict a WAG ratio to be injected into the upper completion interval so as to cause gas injected into the lower completion interval for fluid injection to flow to the upper

boundary of the formation and the completion interval for fluid production at about the same time;

injecting gas and water at selected rates to cause the predicted WAG ratio; and

recovering oil from the completion interval for fluid production.

15. (original) The method of claim 14 further comprising adding a tracer to the gas before injection, measuring the amount of tracer in a fluid sample from the formation and selecting a revised rate and time of injection of water or gas based on the amount of tracer in the fluid sample.

16. (original) The method of claim 14 further comprising adding a surfactant to the gas or water before injection.

17. (original) The method of claim 14 wherein the gas is selected from gases consisting of natural gas, natural gas containing heavier hydrocarbons, nitrogen, carbon dioxide, flue gas and mixtures thereof.

18. (original) The method of claim 17 wherein the gas is miscible with the oil.

19. (original) The method of claim 14 wherein the lower completion interval and the upper completion interval are formed in vertically displaced horizontal wellbores through the formation.

20. (original) The method of claim 14 wherein the lower completion interval and the upper completion interval are formed by perforated intervals in a vertical wellbore.

REMARKS

Claims 1 – 20 stand allowed, as stated in the Office Action mailed 06/01/2007.

In a Notice of Non-Compliant Amendment mailed 08/24-2007, Applicant is required to present proper status identifiers to the claims. The identifiers have now been added, as shown in the clean copy of the specification provided on pages 2-29 and the marked-up version of the claims shown on pages 30-32. A marked-up version of the claims is shown of pages 33-35.

Titles to sections of the specification have also been amended to agree with the Guidelines (MPEP 601). No new matter has been added.

If a fee is required, please accept this transmittal as a petition therefore and charge any fee to Burleson Cooke L.L.P., Deposit Account No. 50-3809.

Yours very truly,

Date: Sept. 10, 2007

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